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Analysis of scapulohumeral rhythm during arm elevation in patients with rotator cuff pathology-an analytical study

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Abstract
Background and Purpose: The shoulder complex mechanism includes scapulothoracic motion and glenohumeral motion during arm elevation. Pathology of rotator cuff muscles will bring mobility deficit in glenohumeral range due to poor muscle control and strength deficits.
Methodology: In this study scapulothoracic rhythm was assessed with two inclinometers which measured glenohumeral elevation and scapular upward rotation. Scapulohumeral rhythm was calculated by taking ratio. Data was analyzed using Wilcoxon matched-pairs signed rank test used for comparison of affected with non-affected side.
Results: Results showed that scapulohumeral rhythm is altered i.e., early scapular upward rotation and total reduced scapular upward rotation is noted for both flexion and abduction movement on affected side. Statistical significance was found in subjects with reduced ROM at glenohumeral joint for SHR during flexion as well as during abduction when compared to non-affected side. Indicating altered scapulohumeral rhythm in rotator cuff pathology patients.
Conclusion: present study concludes that the scapulothoracic mechanism is altered in patients with rotator cuff pathology. Therefore, Assessment of scapulothoracic mechanisms is essential to address glenohumeral pathology and it should also be addressed in the treatment plan.

Keywords: rotator cuff, scapulohumeral rhythm, arm elevation, analysis

Introduction

Rotator cuff pathology includes rotator cuff muscle tear, rotator cuff tendinitis, rotator cuff tendinosis [1]. Tendinitis is inflammation of a tendon; there may be resulting scarring or calcium deposits. Tendinosis is degeneration of the tendon due to repetitive microtrauma [2]. Rotator cuff injury is majorly due to trauma. Which includes macro-trauma causing an acute tear, and is seen generally a younger patient during high speed and overhead activities resulting in a complete tear. Micro-trauma causes tendon degeneration and with insufficient healing, and repetitive activities lead to degenerative tears. A smaller amount of force is needed to cause a complete tear if there is sufficient tendon degeneration, which is more prevalent [1].

A prevalence of 13.1% for acute rotator cuff injury has been reported in the age group of 23- 69 years in a study done amongst the population of Northern India [3]. Prevalence of rotator cuff pathology is 18% in manual labors and is also prevalent in sport person (21.6 %) as well as those in middle (10.7%) and older age (36.6%) [4].

Injury to the rotator cuff muscles compromises function of shoulder joint complex which is arm elevation during frontal and sagittal plane [5]. This affects the stability and mobility of the glenohumeral joint. Rotator cuff is a group of muscles and their tendons that act to stabilize glenohumeral joint and allow for its extensive range of motion. Comprising of supraspinatus, infraspinatus, teres minor and subscapularis [6]. This injury is caused by both intrinsic and extrinsic factors. Intrinsic factors include age related degenerative changes, vascularity and impact of alteration in tendon matrix leading to tensile tissue overload. Extrinsic factors include anatomical factors such as anatomical variants of acromion which can lead to decrease in sub-acromial space. Biomechanical factors include postural scapular abnormality and can be divided into alteration in scapular kinematics and alteration in humeral kinematics. Alterations in any one of the kinematics can cause the pathology [7].

In this, most common rotator cuff muscle which gets injured is supraspinatus 84%, subscapularis along with supraspinatus is 78% followed by infraspinatus and teres minor which is 39% [8]. The supraspinatus muscle function as an abductor for the initial 30 degrees of abduction. It acts as a local stabilizer at glenohumeral joint in both eccentric and concentric contraction and in high speed and loading activity [9]. Therefore, most common cause of acute supraspinatus injury in young athlete is while lifting heavy objects and throwing a ball or swinging a bat. Whereas, Degenerative tears occurs in older population with overuse injury, particularly if the arm is at or above shoulder level during repetitive activities like painting, washing windows, swimming etc [10].

Subscapularis functions as an internal rotator. Injury to this muscle can be caused by overextended arm or due to impingement [11]. The infraspinatus and teres minor muscles function as an external rotator. Injury frequently occurs in overhead athletes or a result of overuse injury or chronic shoulder instability. Most of these activities include overhead reaching, lifting and pushing [12].

Therefore abduction, internal and external rotations are impaired in rotator cuff pathology. Additionally, they all work as stabilizers of the glenohumeral joint during arm elevation. Therefore, stability and mobility both are affected [13]. Pathology of rotator cuff muscles will bring mobility deficit in glenohumeral range due to poor muscle performance & control and strength deficits. Therefore, clinicians normally focus on treating at glenohumeral joint [6]. 61% of rotator cuff pathology patients were still symptomatic at 18 months despite receiving conservative treatment which focuses on basic rotator cuff strengthening and mobility. Treatment consists of gentle stretching and strengthening of rotator cuff muscles. In which 60% patients experienced improvement in general health and 30% experience worsening [14].

Optimal function of the shoulder during arm elevation is synchronous and coordinated movement of scapula and humerus and trunk mechanism. The shoulder complex mechanism includes scapulothoracic motion and glenohumeral motion during arm elevation [5]. Specifically, the kinematic interaction between the scapula and the humerus was introduced in the 1930s and termed "scapulohumeral rhythm by Codman [15].

The scapulohumeral rhythm is therefore defined as the ratio of the glenohumeral movement to the scapulothoracic movement during arm elevation. The overall ratio of 2:1 during arm elevation is commonly used. According to the 2-to-1 ratio frame-work, flexion or abduction of 90° in relation to the thorax would be accomplished through approximately 60° of GH and 30° of ST motion [15].

Inman *et al*. reported, while performing flexion or abduction, the glenohumeral (GH) joint contributes 100°-120°. The scapula on the thorax contributes to elevation of the humerus by upwardly rotating the glenoid fossa 50° to 60° from its resting position. In this early phase for flexion (0-60°) and for abduction 0–30-degree motion occurs primarily at the GH joint [16]. Amy G Mell observed that patients with rotator cuff pathology have altered shoulder kinematics with alteration in scapulothoracic mechanics [17].

Similarly, Xavier Robert-Lachaine *et al*. reported, if mobility deficit is at glenohumeral joint there will be compensatory mechanism at scapulothoracic joint to achieve function of arm elevation [18]. Therefore hypomobility at glenohumeral joint will lead to hypermobility at scapulothoracic joint. Thus, assessment of scapulothoracic mechanism by assessing scapulohumeral rhythm is essential to address glenohumeral pathology. So that while tackling rotator cuff pathology assessment and management of altered scapulothoracic mechanism should be included.

There is ample research work done regarding treatment at glenohumeral joint for rotator cuff pathology but there is paucity of literature for treating rotator cuff pathology which includes correction of scapulothoracic mechanism. Hence in patients with rotator cuff pathology analysis of scapulothoracic mechanism in arm elevation for both frontal and sagittal plane is necessary. Physiotherapy treatment interventions should also aim at improving stability at the scapulothoracic joint to achieve optimal function of the shoulder in arm elevation.

Aim

To analyze the scapulohumeral rhythm during arm elevation in patients with rotator cuff pathology

Objectives

1. To assess the range of motion of the glenohumeral joint in flexion and abduction movement while performing arm elevation.
2. To assess the range of motion of scapular upward rotation in flexion and abduction movement while performing arm elevation.
3. Derive scapulohumeral ratio in arm elevation i.e. flexion and abduction movement.
4. Compare scapulohumeral rhythm of affected side with the unaffected side of the patient.

Hypothesis

Null Hypothesis [H0]: There is no significant difference between Scapulohumeral rhythm during arm elevation on affected and non-affected side in patients with rotator cuff tear.

Alternate Hypothesis [H1]: There is significant difference between Scapulohumeral rhythm during arm elevation on affected and non-affected side in patients with rotator cuff tear.

Methodology

- **Study type:** Analytical cross-sectional study
- **Duration of study:** 6 months
- **Sampling method:** Convenient sampling
- **Sample size:** 72
- **Eligibility Criteria**

Inclusion criteria

1. Rotator cuff pathology patients - Partial tears of rotator cuff, Rotator cuff tendinitis, Rotator cuff tendinosis.
2. Both males and females.
3. Age group: 20 to 50 years.
4. Both conservatively and operated patients for rotator cuff pathology
5. Patients medically diagnosed with rotator cuff pathology.
6. Any three positive test from following [19]: Lift off test/belly press test, Bear hug test, Jobe’s test, Hornblower’s sign.

Exclusion criteria

1. Patients with Bicipital tendinitis – positive speeds test, Bursitis, Complete rotator cuff muscle tear-positive drop arm test,
2. History of Fractures at scapula, clavicle, humerus, Shoulder dislocations.
3. Any infective, inflammatory and neoplastic condition of the shoulder.
4. Vascular conditions.

Procedure

- Subjects from physiotherapy department were recruited in this study.
- Informed consent was taken.
- Individuals were enrolled in the study as per inclusion and exclusion criteria.
- All subjects were assessed in a relaxed, standing (barefoot) position.
- Subjects were asked to perform full extension at the elbow, neutral wrist position, and with the thumb leading in the coronal plane.
- Measurement of glenohumeral range for arm elevation in frontal and sagittal plane was taken with inclinometer and noted down.
- Upward rotation of scapula with respect to glenohumeral joint was assessed with scapular inclinometer.

- Subjects were asked to actively move their arms (non-affected and affected) from rest position to 30, from rest position to 60 and from rest position to 90 degrees of elevation in frontal and sagittal plane and to hold arm in these positions for measurement (measured with first inclinometer).
- Documentation was done at30 degrees, 60 degrees, 90 degrees and at the available end range.
- Assessment of scapulohumeral rhythm was done on both side affected and non-affected side of the patient.
- Scapulohumeral rhythm was assessed by calculating scapulohumeral ratio and compared with the unaffected side of the patient and data will be collected and statistically analyzed.

Assessment of glenohumeral range of motion [20]

- First inclinometer is attached parallel to the humerus, just under the deltoid insertion with the use of Velcro straps.
- Standing posture and postural sway is controlled by asking subjects to look at target approximately 2m ahead of them positioned at eye level.
- Range of motion will be documented by inclinometer in sagittal and frontal plane at glenohumeral joint in arm elevation.
- Three trials with 30 seconds rest in between the trials were done, and means of them were calculated.

Assessment of scapular upward rotation [20]

- Scapular upward rotation was measured using a second inclinometer; this was achieved by manually aligning the base of the inclinometer along the spine of the scapula.
- Range of scapular upward rotation was documented by an inclinometer in the sagittal and frontal plane in arm elevation in 30, 60, 90 degrees and in the available end range.
- Three trials with 30 seconds rest in between the trials will be done, and means of them will be calculated.

Deriving scapulohumeral ratio [20]

- The ratio of glenohumeral motion to scapular motion was then calculated to derive scapulohumeral rhythm ieGlenohumeral motion = total shoulder motion – scapular upward rotation
- Scapulohumeral rhythm = Glenohumeral elevation / scapular upward rotation
- While assessing range of motion at glenohumeral joint assessment of end feel, joint reactivity and irritability will be done with Maitland concept.
- Two inclinometers were used to measure humeral elevation and scapular upward rotation in 30, 60 and 90 degrees of arm elevation during flexion and abduction.
- Using an electromagnetic tracking system, Johnson *et al*. (2001) validated use of the inclinometer to quantify scapular upward rotation associated with varying amounts of humeral elevation (r ¼ 0.66e0.89) with good Intraclass correlation coefficient (ICC ¼ 0.86-0.91) for measurement of scapular upward rotation.

Statistical analysis

Data for statistical analysis was entered using MS-Excel 2010, Statistical Analysis was performed using SPSS version 15. Kolmogorov-Smirnov test was used to check normality of the data. Scapulohumeral rhythm of affected and non-affected side for both flexion and abduction did not pass the normality test. Hence, non-parametric test, i.e., Mann Whitney test was used for comparison of affected with non-affected side. Mean and standard deviation was calculated for scapular upward rotation at 30, 60 and 90 and compared with non-affected side using line graph. Significance value was set at $p \leq 0.05$.

Results

The total of 72 study subjects consisted of 34 males and 38 females each. The mean age for the total study population was 41.17 ± 7.63 years. Similarly, the mean weight and height were 66.3 ± 10.09 kg and 161.0 ± 0.08 cm respectively. The mean BMI for the total study population was 25.52 ± 4.2 kg/m^2. Out of 72 subjects 22 subjects had comorbidities (30.55% of total population) in which 11 patients had HTN 12 with DM and 3 patients had Thyroid. (Table-1).

Among 72 patients with rotator cuff pathology, medial border is prominent in 38.88% subjects followed by inferior angle prominence of 22.22% and elevated scapula in 18.05% and depressed scapula in 6.9% patients. Indicating altered scapula posture at rest in 85.24 % of subjects (Figure-1).

At 30 degrees of flexion, scapular upward rotation on the affected side was found to be 6.1806 ± 3.6257 degrees, when compared to the non-affected side which is 0.90 ± 2.02 degrees. Indicating scapular motion starts early in range of motion (i.e., in Setting Phase). Total scapular upward rotation is reduced, on the affected side which is 39.02 ± 7.07 degrees compared to the non-affected side which is 54.57 ± 6.27 degrees (Table 2).

At 30 degrees of abduction, scapular upward rotation on affected side was found to be 5.65 ± 3.78 degrees, when compared to non-affected side which is 0.71 ± 1.77 degrees. Indicating scapular motion starts early in range of motion (i.e., in Setting Phase). Total scapular upward rotation is reduced, on affected side which is 38.65 ± 13.94 degrees, compared to the non-affected side which is 54.08 ± 7.0 degrees. (Table 2).

Scapulohumeral rhythm is altered in affected side (2.59:1± 1.23:1) when compared to non-affected side (2.34:1 ± 0.42:1) while performing flexion, but is not statistically significant (P = 0.0981). Total ROM in the affected side is (140.69 ± 41.43) when compared to the non-affected side (179.86 ± 1.17) is statistically significant (P<0.0001). Scapular UR is reduced in the affected side (39.72 ± 7.07) when compared to the non-affected side (54.57 ± 6.27) with statistically significant (P<0.0001) (Figure-2, Table-3).

Scapulohumeral rhythm is altered in affected side (2.37:1 ± 1.24:1) when compared to non-affected side (2.36:1 ± 0.45:1) while performing flexion, but is not statistically significant (P = 0.6283) But total ROM in affected side is (126.02 ± 49.64) when compared to non-affected side (179.86 ± 1.17) is statistically significant (P<0.0001). Scapular UR is reduced in the affected side (38.65 ± 13.94) when compared to the non-affected side (54.08 ± 7.00) with statistically significant (P<0.0001) (Figure-3, Table-3).

Reduced ROM for GH (n= 24), in this group the ROM of the affected side (102.5 ± 43.39) is significantly reduced when compared to the non-affected side (179.58 ± 1.99) with P <0.0001. Reduced scapular UR on the affected side (40.67 ± 15.46) when compared to the non-affected side

(56.21± 4.73) P<0.0001. Therefore, there is reduced SHR on the affected side (1.45:1 ± 0.43:1) compared to the non-affected side (2.21:1 ± 0.29:1) with a significant difference of P<0.0001 (Table-4).

Near normal ROM for GH (n= 48) in this group the ROM of the affected side (159.67 ± 23.22) is significantly increased than the other group but less when compared to the non-affected side (180.0 ± 0.0) with P <0.0001. Reduced scapular UR on the affected side (40.22 ± 9.26) when compared to the non-affected side (56.76± 6.76) P<0.0001. Therefore, there is increased SHR on the affected side (3.06:1 ± 1.16:1) compared to the non-affected side (2.36:1 ± 0.58:1) with significant difference of P<0.0001 (Table-4).

Reduced ROM for GH (n= 33), in this group the ROM of the affected side (94.75 ± 41.07) is significantly reduced when compared to the non-affected side (179.69 ± 1.71) with P <0.0001. Reduced scapular UR on the affected side (38.77 ± 14.80) when compared to the non-affected side (55.30 ± 6.27) P<0.0001. Therefore, there is reduced SHR on the affected side (1.39:1 ± 0.36:1) compared to the non-affected side (2.23:1 ± 0.29:1) with significant difference of P<0.0001 (Table-5).

Near normal ROM for GH (n= 39) in this group the ROM of the affected side (152.48 ± 39.92) is significantly increased than other group but less when compared to the non-affected side (180.0 ± 0.0) with P <0.0001. Reduced scapular UR on the affected side (38.54 ± 13.17) when compared to the non-affected side (53.05 ± 7.42) P<0.0001. Therefore, there is increased SHR on the affected side (3.21:1 ± 1.10:1) compared to the non-affected side (2.41:1 ± 0.67:1) with significant difference of P<0.0001) (Table-5).

Table 1: Descriptive statistics of Rotator cuff pathology subjects:

Variables		**RC Pathology subjects**		
Age (years)		41.17 ± 7.63		
Gender	M	47.78 %		
	F	52.22 %		
Height (m)		1.61 ± 0.08		
Weight (kg)		66.3 ± 10.09		
BMI (kg/m^2)		25.52 ± 4.2		
Side Affected	Left	30.66%		
	Right	69.44%		
Comorbidities		22 (30.55 %)		
		HTN:11	DM:12	Thyroid:3

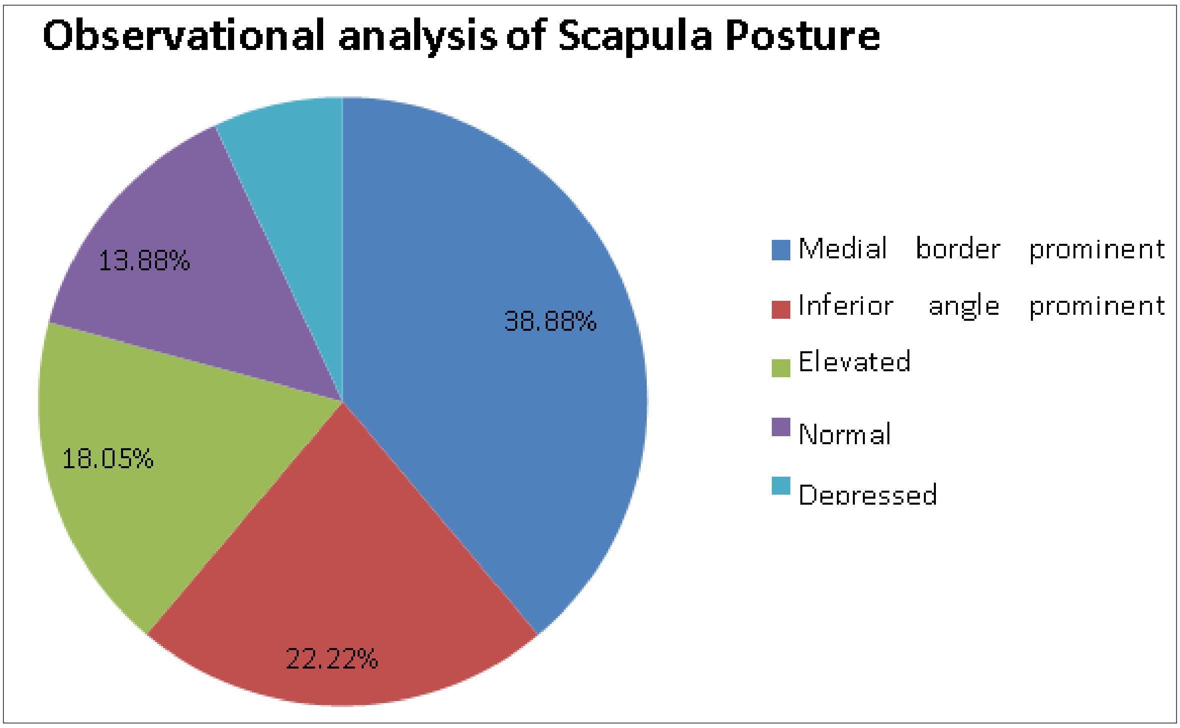

Fig 1: Observational analysis of most prominent scapula posture at rest on affected side

Table 2: Upward rotation of scapula (Mean ± SD) at 30, 60, 90 degrees and at end available ROM during arm elevation in flexion and abduction.

	For Flexion		**For Abduction**	
ROM	Affected side	Non affected side	Affected side	Non affected side
At 30	6.18 ± 3.63	0.90 ± 2.02	5.65 ± 3.78	0.71 ± 1.77
At 60	11.83 ± 4.64	6.69 ± 8.86	13.02 ± 4.69	7.57 ± 2.84
At 90	19.97 ± 5.38	16.69 ± 6.20	24.16 ± 7.17	17.69 ± 4.96
At end available ROM	39.72 ± 7.07	54.57 ± 6.27	38.65 ±13.94	54.08 ± 7.0

Table 3: Altered Scapulohumeral rhythm (SHR) in patients with rotator cuff pathology for flexion and abduction. (n=72)

	For flexion			**For Abduction**		
For flexion	Affected Side	Non-affected side	P Value	Affected Side	Non-Affected Side	P Value
Total ROM	140.69 ± 41.43	179.86 ± 1.17	P < 0.0001	126.02 ± 49.64	179.86 ± 1.17	P < 0.0001
Scapular UR	39.72 ± 7.07	54.57 ± 6.27	P < 0.0001	38.65 ± 13.94	54.08 ± 7.00	P < 0.0001
SHR	2.59:1 ± 1.23:1	2.34:1 ± 0.42:1	P = 0.0981	2.37:1 ± 1.24:1	2.36:1 ±0.45:1	P = 0.6283

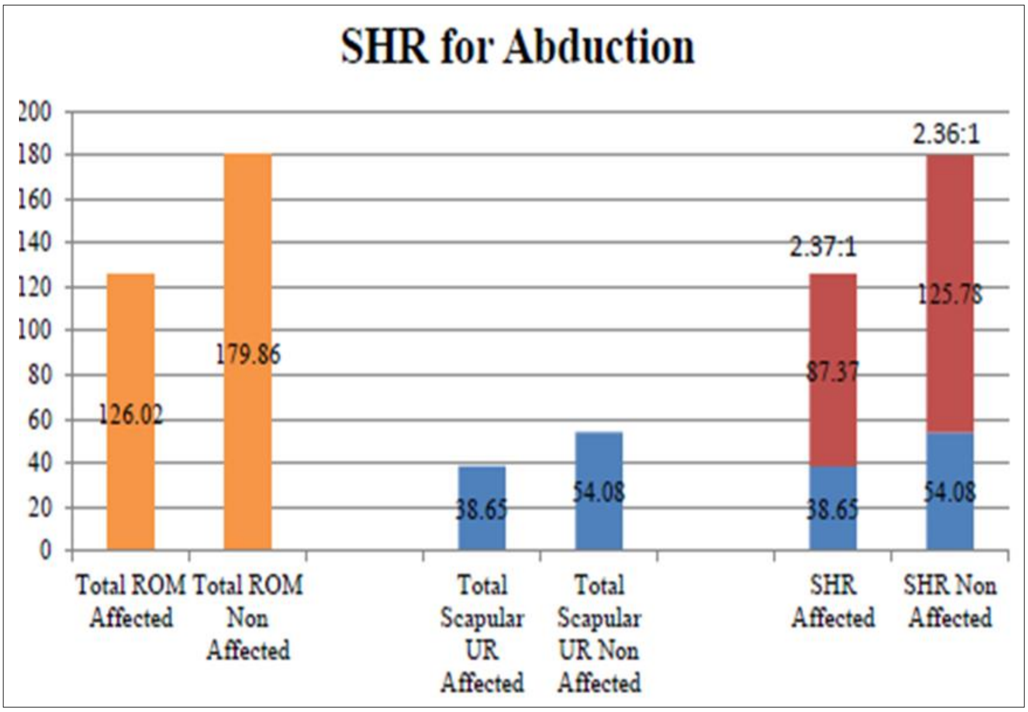

Fig 2: Altered Scapulohumeral rhythm (SHR) in patients with rotator cuff pathology for flexion. (n=72)

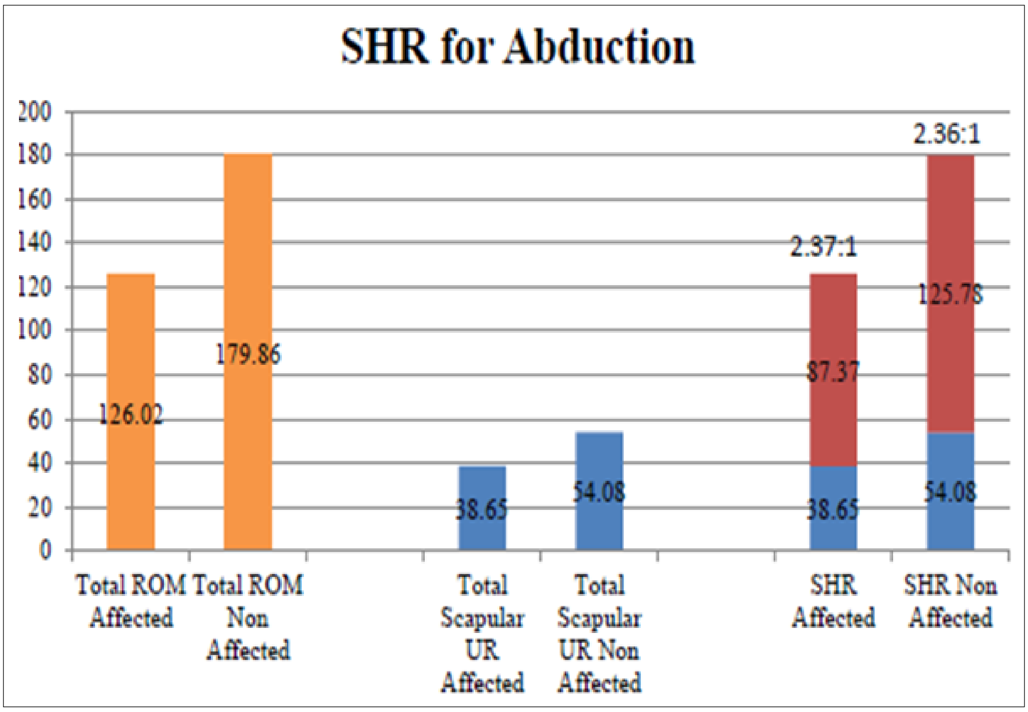

Fig 3: Altered Scapulohumeral rhythm (SHR) in patients with rotator cuff pathology for abduction. (n=72)

Table 4: Subgrouping of SHR while performing flexion, according to mobility at GH joint.

For Flexion	Reduced ROM for GH (n = 22)	Non-Affected Side	P Value	Near normal ROM for GH (n = 48)	Non- affected side	P Value
Total ROM	102.5± 43.39	179.58 ± 1.99	P < 0.0001	159.67± 23.22	180.0 ± 0.0	P < 0.0001
Scapular UR	40.67± 15.46	56.21 ± 4.73	P < 0.0001	40.22 ± 9.46	53.76 ±6.76	P < 0.0001
SHR	1.45:1± 0.43:1	2.21:1 ± 0.29:1	P < 0.0001	3.06:1 ± 1.16:1	2.36:1 ± 0.58:1	P <0.0001

Table 5: Subgrouping of SHR while performing abduction, according to mobility at GH joint.

For Abduction	Reduced ROM for GH (n = 22)	Non-Affected Side	P Value	Near normal ROM for GH (n = 48)	Non-affected side	P Value
Total ROM	94.75 ± 41.07	179.69± 1.71	P < 0.0001	152.48 ±39.92	180.0 ± 0.0	P < 0.0001
Scapular UR	38.77 ± 14.80	55.30 ± 6.27	P < 0.0001	38.54 ± 13.17	53.05 ± 7.42	P < 0.0001
SHR	1.39:1 ± 0.36:1	2.23:1 ± 0.29:1	P < 0.0001	3.21:1± 1.10	2.41:1 ± 0.67:1	P <0.0001

Discussion

In this study subjects studied had altered resting scapula posture, which could have given rise to muscle length imbalance, giving rise to altered activation pattern of serratus anterior, pectoralis minor and in levator scapulae muscles [21]. Also, very minimal activity is required from middle trapezius and lower trapezius muscles to maintain normal scapula posture [22]. These findings could have been confirmed with assessment of muscle length. As it was not an objective of this study these were not included.

This altered muscle activation pattern was seen by early scapular upward rotation in the setting phase. During flexion 6.1806 ± 3.6257 degrees and for abduction 5.65 ± 3.78 degrees of scapular upward rotation was noted in the setting phase when compared to non-affected side flexion was 0.90 ± 2.02 degrees and for abduction was 0.71 ± 1.77 degrees. Mell *et al* in their study had reported similar findings of 8.1 degrees scapular upward rotation in setting phase in RC tendinopathy subjects and 5.14 degrees scapular upward rotation in RC tears subjects [17]. The above findings indicate that while performing flexion and abduction, the scapula starts moving early in the ROM indicating altered scapulohumeral rhythm.

Inman *et al* stated that upto the first 60° of flexion and 30° of abduction, the scapula remains fixed or slightly moves medially or laterally [16]. This was identified as the initial scapular "setting phase." Most of the motion during this phase occurred at the glenohumeral joint. In the initial 60 degrees for flexion and 30 degrees for abduction movement is majorly occuring at glenohumeral joint with scapula resting on thorax with optimal activation of scapular stabilizing muscles [23]. The thoracoscapular muscles must move the scapula correctly for the scapulohumeral muscles to provide optimal control of the humerus and to maintain an optimal relationship of the glenoid and humeral head [23].

It can be hypothesized that the middle trapezius and lower trapezius might not be optimally working to keep the scapula in resting position [24]. If these muscles do not maintain appropriate length tension relation with optimal activation for maintaining stability at the scapulothoracic joint, the scapula will start moving early in the ROM with upward rotation or any other compensatory pattern.

This study also reported that along with early scapular motion in the setting phase, total scapular upward rotation was reduced for flexion 39.72 degrees and for abduction 38.65 degrees. When compared to normative values of 60 degrees of scapular upward rotation according to 2:1 ratio, where 120 degrees of glenohumeral motion is accompanied by 60 degrees of scapular upward rotation in the 2nd phase of arm elevation that is once setting phase of scapula is over [23].

Similar results were found by Ludwig and Cook who studied scapular kinematics in patients with impingement syndrome. They reported reduced scapular upward rotation when compared to the control group [25]. Endo *et al* also noted decreased scapular upward rotation in unilateral impingement patients [26]. In a study done on impingement syndrome in swimmers, Su *et al* also found decreased scapular upward rotation [27].

The total upward rotation of the scapula is caused by the force couple of upper trapezius, lower trapezius and serratus anterior muscles [28]. Alteration in the dominance of any one muscle will cause muscle imbalance. Therefore efficient activity of trapezius and Serratus anterior muscle both are important. 41.66% of subjects along with early motion of the scapula in the setting phase and reduced total scapular upward rotation also showed other compensatory patterns of elevation, adduction and downward rotation of the scapula during flexion and abduction movement. This also indicates altered activation of scapular muscles mainly levator scapulae and rhomboids [29].

During further analysis of the data, it was observed that 24 subjects had reduced range for glenohumeral elevation and 48 had near normal range of motion contribution from glenohumeral elevation during flexion. Same pattern was also observed during abduction movement where 33 subjects had reduced range for glenohumeral elevation and 39 had near normal range of motion contribution from glenohumeral elevation. However all subjects had reduced scapular upward rotation.

The total ROM for subjects having reduced contribution from GH joint while performing flexion was 102.5 degrees and for abduction was 94.74 degrees. This reduced GH mobility can be due to pain arising from subacromial impingement of RC tendons and due to reduced scapular upward rotation [26, 27].

Xavier *et al* in symptomatic rotator cuff tears patients reported reduced ROM at the glenohumeral joint. The subject population was divided into two groups, one with maximal arm elevation of 85 degrees and other with 40 degrees. This reduced ROM at the glenohumeral joint was compensated by increased contribution from the scapulothoracic joint [18]. In case of present study, compensation of scapula was present early in the ROM of arm elevation; however total scapula upward rotation was reduced.

This study also reported, the total ROM for near normal ROM contribution from glenohumeral joint during flexion movement was 159.67 degrees and for abduction movement was152.48 degrees. When compared to the normal total range of elevation as reported in literature 168-172 degrees by Culham *et al* [30]. In total arm elevation, glenohumeral joint contributes 120 of flexion and abduction with 60 degrees of scapular upward rotation resulting in a maximum range of 180 degrees, as per 2:1 ratio [23]. It was observed that total scapular upward rotation was reduced with compensatory motion from the glenohumeral joint.

We can hypothesize the reason behind this increased contribution from the gleohumeral joint in this study can be attributed to ligament laxity at glenohumeral joint. Poor scapula stability mechanics have been associated with increased laxity of anterior glenohumeral structures [31]. As generalised ligament laxity is commonly seen in the subjects with shoulder instability as reported by literature [32]. Assessment of ligament laxity could have been done to confirm these findings.

Statistical significance of P<0.0001 was found in subjects with reduced ROM at glenohumeral joint for SHR during flexion was 1.45:1 ± 0.43:1 when compared to the non-affected side 2.21:1 ± 0.29:1. Similarly SHR for abduction was 1.39:1 ± 0.36:1 when compared to the non-affected side 2.23:1 ± 0.29:1. Similar findings are present for scapulohumeral rhythm in subjects having near normal ROM contribution from GH motion during flexion was 3.06:1 ± 1.16:1, when compared to the non-affected side 2.36:1 ± 0.58:1 and for abduction was 3.21:1±1.1 when compared to the non-affected side 2.41:1 ± 0.67:1. Several authors have discussed the factors explaining modified glenohumeral and scapulothoracic coordination with RC pathology, the most common factors being structural damage which directly interfere with motion mechanics and pain avoidance, which should alter shoulder kinematics [33,34,35].

Rotator cuff muscles stabilize the humeral head in the glenoid cavity. In subjects with rotator cuff pathology the downward pull of the humerus by the rotator cuff muscles might be insufficient to counteract the upward pull from the deltoid, giving rise to impingement of Rotator cuff tendons [35,36]. This could be the reason for reduced glenohumeral ROM in some subjects in this study. Phadke *et al.* also suggest that reduced rotator cuff activation may relate to inadequate humeral head depression or excess superior translation of the humerus during the critical first portion of elevation of the arm in subjects with shoulder impingement [37].

Hence the assessment of scapulohumeral rhythm with scapulohumeral ratio should be an integral part of physiotherapy management. Also one of the factors for altered scapulohumeral rhythm is resting scapula posture. Therefore, assessment of scapula posture is also necessary. Finding the cause of this altered scapulohumeral rhythm will help in management of rotator cuff pathology patients. Hence, correction of this altered scapulohumeral rhythm and scapula posture should be included in the treatment protocol for cost and time effectiveness. This could improve the patient’s physical function and participation in society

Conclusion

The present study concludes that the patients with rotator cuff pathology showed altered scapulohumeral rhythm in arm elevation for both flexion and abduction movement. Early motion of scapular upward rotation in setting phase and total reduced scapular upward rotation and is documented in rotator cuff pathology patients. Scapulohumeral rhythm ratio can be increased or it can be reduced. Therefore while treating rotator cuff pathology patients, assessment of scapulohumeral rhythm and scapula posture should be done. Physiotherapy treatment interventions should also focus on improving stability at the scapulothoracic joint while treating rotator cuff pathology patients.

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